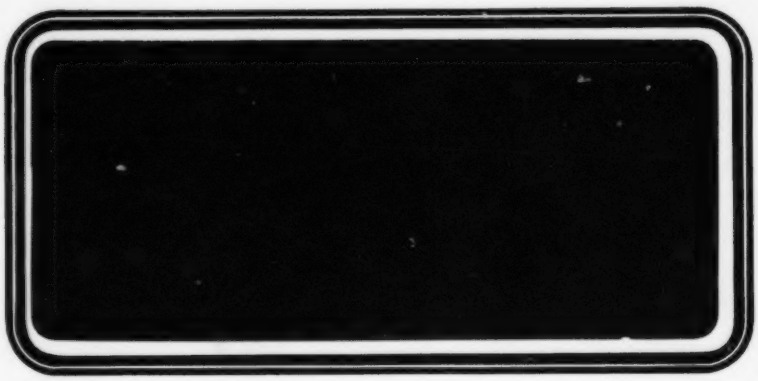
Canada Alberta

FOREST RESOURCE DEVELOPMENT AGREEMENT
ENTENTE SUR LA MISE EN VALEUR DES RESSOURCES FORESTIERES



Canada Alberta

The Canada-Alberta Forest Resource Development Agreement is a subsidiary agreement of the Canada-Alberta Economic and Regional Development Agreement, which provides coordination and cooperation between the governments of Alberta and Canada in areas of Alberta's economic development.

The Canada-Alberta Forest Resource Development Agreement is funded equally by the governments of Canada and Alberta, from April 1, 1984, to March 31, 1989.

Its primary objectives are to ensure the long-term availability of timber supplies; to optimize timber uses; and to contribute to the growth and diversification of Alberta's economy.

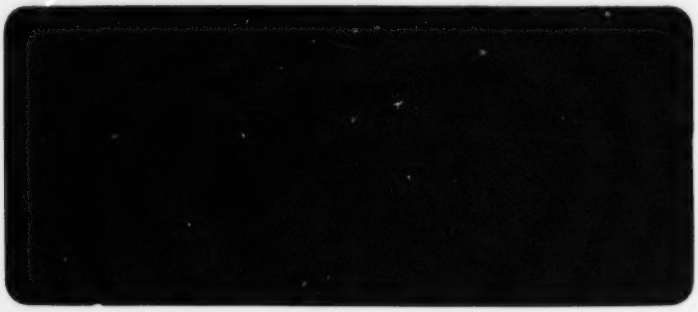
The Agreement comprises three programs: Reforestation; Applied research, technology transfer and opportunity identification; and Public information, evaluation and administration. These programs are managed by a joint Directorate and are implemented by the Canadian Forestry Service and the Alberta Forest Service.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est auxiliaire à l'Entente Canada-Alberta sur le développement économique et régional, qui vise à assurer la coordination et la coopération des deux gouvernements relativement au développement économique de l'Alberta.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est financée à parts égales par les gouvernements du Canada et de l'Alberta, et a cours du 1er avril 1984 au 31 mars 1989.

Ses objectifs principaux sont assurer la disponibilité à long terme de réserves de bois; optimiser leur utilisation; et contribuer à la croissance et la diversification de l'économie de la province.

L'Entente comprend trois programmes: Reboisement; Recherche appliquée, transferts de connaissances techniques et relevé des occasions; et Information, évaluation et administration. Ces programmes sont gérés par un Bureau de direction conjoint, et mis en oeuvre par le Service canadien des forêts et le Service forestier de l'Alberta.



For more information, please call or write:

Pour de plus amples informations, veuillez vous adresser à:

Canadian Forestry Service
Northern Forestry Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5
Telephone: (403) 435-7210
Attention: S. Price

OR/OU Alberta Department of
Forestry, Lands & Wildlife
9915 - 108 Street
Edmonton, Alberta
T5K 2C9
Telephone: (403) 427-3583
Attention: D. Fregren

ON-LINE SYSTEM FOR BOARD PRODUCT QUALITY CONTROL

Glen Byers
Pelican Spruce Mills Ltd.[1]
1988

This is a joint publication of the Canadian Forestry Service and the Alberta Forest Service pursuant to the Canada-Alberta Forest Resource Development Agreement

This paper was presented at the Particleboard/Composite Materials Symposium March 22-24, 1988, Washington State University, Pullman, Washington.

[1]Edmonton, Alberta

89-05234/

DISCLAIMER

The study on which this report is based was funded under the Canada-Alberta Forest Resource Development Agreement.

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ISBN 0-662-16280-3

Catalogue No. Fo 42-91/47 - 1988E

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Regional Development
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ABSTRACT

This paper presents an application of on-line and non-contact measuring system for reconstructing profiles of weight per unit area, density and thickness of manufactured board products.

A high density matrix of spot measurements is provided by the system in real time, as the product advances through the gage assembly. With a specific configuration of the measuring components and system hardware the resolution of individual rows of spot measurements could be in the range of 2" for production speed up to 300 feet per minute.

The technology of measurements is based on the improved art of non-destructive techniques utilizing penetrating radiometry (low energy Gamma radiation) and methods of ultrasound propagation.

The unique design of the system components and their configuration contributes to high stability and accuracy of measurements of +/- 3% for weight/density and +/- 0.005" for thickness, at line speed up to 300 feet per minute. Data from the system can be used for automatic grading of the product, process control interface and for product quality monitoring.

INTRODUCTION

The processing of wood flakes into O.S.B. boards is a complex task, and from its very beginning at the green end to the final pressing of boards in the press there are many parameters that are very critical to the mechanical strength of the product and its overall quality. The information about how to optimize the production procedure can be derived from measurements of the product taken directly on-line.

In every board production plant monitoring of the density of the product can not be neglected. Parameters of interest are: average density, and density profiles in directions along, (or across) the board. The first one depends on board composition, the second one describes performance of the production line such as uniformity of surface and core forming lines, quality of the press, etc. If density measuring process is slow it can be performed only outside the production line. In this case there is no immediate feedback neither to the process control nor to the board grading and the information can be used only as a general indication of production status.

It is of primary importance to be able to monitor such parameters as thickness and density of boards during the production cycle in on-line conditions. In the plants in Edson and Drayton Valley there are two on-line density measuring

systems recently installed to accompany existing systems for monitoring thickness of boards. The purpose of this paper is to present the principle of operation of the new density monitoring system, the results it provides and the evaluation, based on our experience as users, of the on-line system for density measurement.

Density measuring techniques could be classified into two main groups: as gravimetric and radiation techniques. The latter could be then discussed as being off-line or on-line systems according to their application.

Gravimetric methods are based on measurements of weight and volume of boards, ASTM Standards (1986). They are performed off-line by cutting small samples out of a board and measuring values of their volume and weight. An on-line version of gravimetric method could be a scale mounted under the conveyor and measuring weight of boards. The weight combined with known dimensions of boards could give an estimate of their average density. The off-line version is slow but more accurate and can provide data for density gradients in two dimensions: along and across the board.

Radiation method of density measurement is based on attenuation of electromagnetic radiation by a board being measured, Knoll (1979). Two techniques, X-ray and Gamma-ray may be distinguished in the class.

X-ray technique is often used to produce radiographic negative of investigated samples. Those negatives are later calibrated and read by a densitometer, or serve as an indication of density irregularities.

Gamma-ray technique is based on direct measurement of Gamma radiation penetrating the board. The radiation is produced by a radioactive isotope. The thicker and heavier the board the less radiation can penetrate through it, Radiological Health Handbook (1970). Various applications can differ in activity and type of a source and in detector arrangement. Gamma-ray technique is very fast and can be directly applied for on-line measurements.

SYSTEM DESCRIPTION

The density measuring system described in this paper had two major components. The first one, physically located on the production line, consisted of a metal frame with a set of radioactive sources, detectors and electronics performing sensor data acquisition, while the second one, placed in the Control Room, consisted of the main computer performing all calculations, data display and storage functions as well as interfacing with the process control, see Figure 1.

A basic measuring unit of the system was a pair: a radioactive source and a detector. In the described application there was five such pairs. The electromagnetic energy (Gamma radiation) emitted by the source in the form of a narrow beam penetrated the board being measured and then reached the detector. The presence of the board across the radiation path caused energy attenuation resulting in a difference between the original and the attenuated radiation exposure rate indicated by the detector. This difference depended on board density and was used for density measurements.

The radioactive sources contained an Am-241 isotope of 100 mCi activity and were of sealed type. Each source was placed in a container provided with a shutter and safety interlocks. The source with low energy radiation (60 keV) was chosen to match the characteristics of materials being measured.

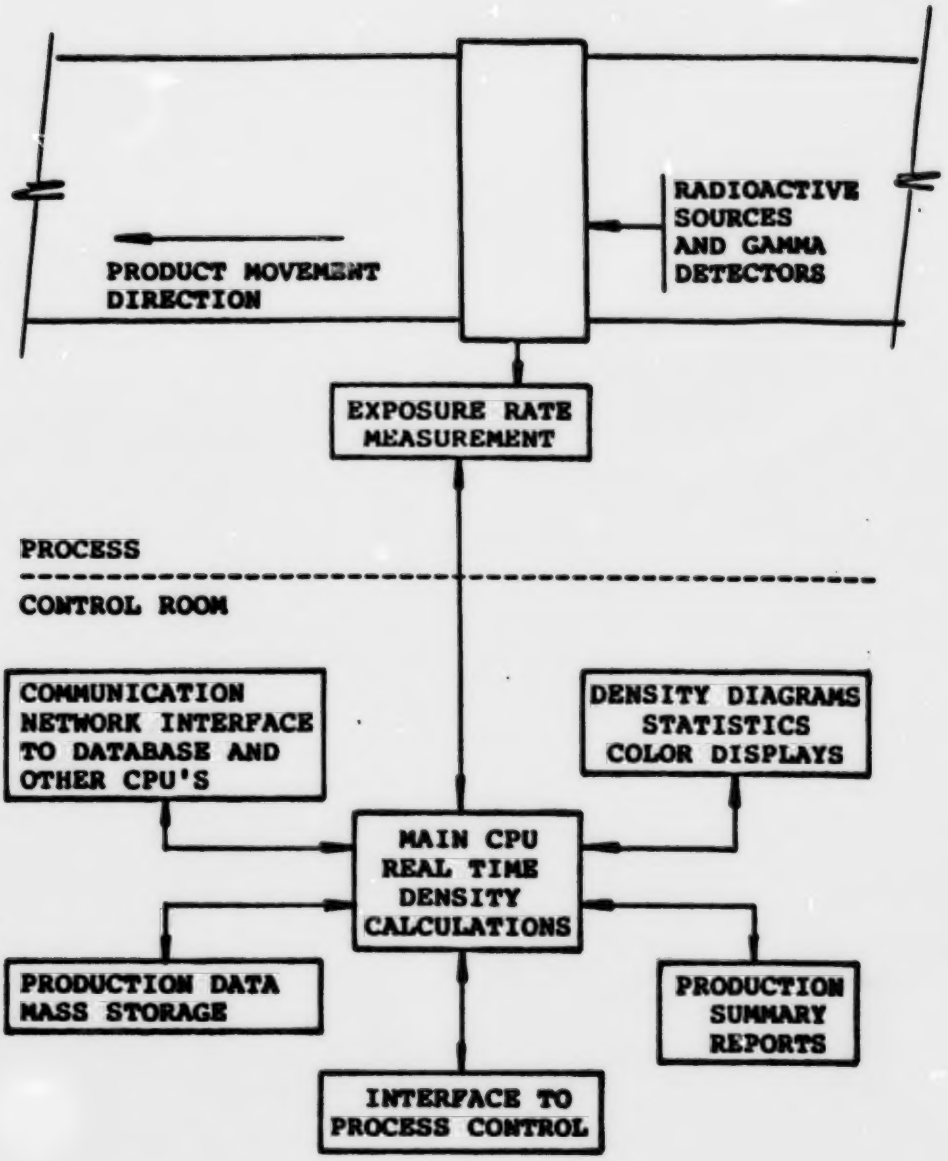

RADIOACTIVE SOURCES AND GAMMA DETECTORS
PRODUCT MOVEMENT DIRECTION
EXPOSURE RATE MEASUREMENT
PROCESS
CONTROL ROOM
COMMUNICATION NETWORK INTERFACE TO DATABASE AND OTHER CPU'S
DENSITY DIAGRAMS STATISTICS COLOR DISPLAYS
MAIN CPU REAL TIME DENSITY CALCULATIONS
PRODUCTION DATA MASS STORAGE
PRODUCTION SUMMARY REPORTS
INTERFACE TO PROCESS CONTROL

Figure 1. Simplified block diagram of the density measuring system.

The detectors used for monitoring radiation exposure rate were inorganic scintillation detectors based on a NaI(Tl) crystal. Both the construction of the detectors and their performance had been optimized to measure the radiation from Am-241 source in an industrial environment with high accuracy. The frame assembly containing radioactive sources and detectors is shown in Figure 2.

The concept of covering a moving board with a grid of measurement points was implemented by placing five pairs of radioactive source and a detector across the production line. The set of detectors was controlled by a local microprocessor that assured that the output was ready for transfer at a requested moment of time. The data from the processor was transferred to the main computer via an RS-232C serial line, so the system could be remotely operated from the Control Room.

The main CPU that performed real-time measurements, computations, and display of the results was a DEC PDP-11 minicomputer with RSX-11M operating system. It calculated density variations of a product, provided statistical analysis of accumulated data, displayed the data on a high resolution monitor, activated alarms and sent all the results to a data base, as shown in Figure 1.

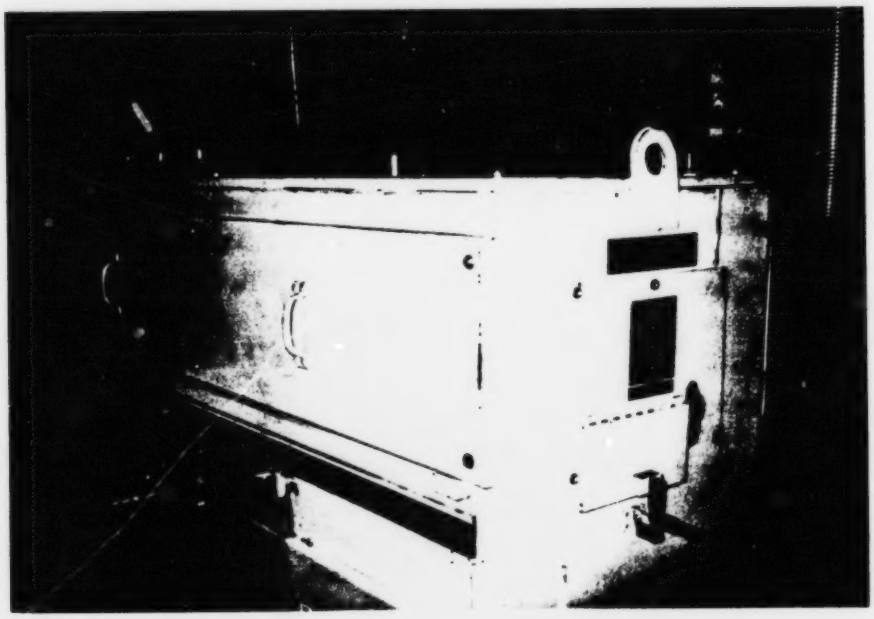


Figure 2. Density measuring system, on-line gage assembly.

Density values for each board were displayed in the form of board contours filled with colour coded measurement results, in such a way that the entire pressload could be verified at the same time. Statistical data about each board was provided in the form of density histograms showing average density of each press load and production trend were updated on the screen.

The PDP-11 computer was interfaced bilaterally with PLC controllers by means of communication package that constituted part of the system and also was communicating with other computers via standard communication network.

DENSITY MEASUREMENT RESULTS AND DISCUSSION

Gamma radiation absorption in narrow beam conditions, Knoll (1979), is described by the law:

$$I = Io \exp(-Q\, nt) \qquad (3.1)$$

where I - attenuated radiation exposure rate [counts/s]

Io - original radiation exposure rate [counts/s]

Q - mass attenuation coefficient [sq cm/g]

n - absorber density [g/cu cm]

t - absorber depth (thickness) [cm]

Formula (3.1) applies to all materials including pure wood and composite wood products. Parameter that characterizes the material as an absorber is its mass attenuation coefficient Q. Once Q is known for a certain material its basis weight nt in [g/sq cm] can be calculated from (3.1) as

$$nt = \frac{\ln(Io/I)}{Q} . \qquad (3.2)$$

If a thickness t of an absorber is known then the density n in [g/cu cm] can be calculated. The computerized density measurement is then a combination of processing of raw sensor

output and mathematical computations performed during on-line measurements in real-time.

Figures 3 to 6 show examples of density measurements taken for a 3/8", 8' by 24' board during its travel through frame assembly with density and thickness gages. The travel time for each board was approximately 7.5 s. Variations of density (standard error about 6%) were recorded by all detectors. Local sharp density drop indicated by detector 3, 4 and 5 show a weak spot in the front left part of the board. After the board was cut into 4' by 8' panels, the one with a defect was localized and rejected.

The accuracy of the system was determined by a statistical error of nuclear counting and depended on the activity of a source, the distance between a source and a detector and indirectly on speed of boards on the production line. In the operating conditions an error due to the random nature of nuclear radiation, measured in time interval allowing for 4 spot measurements per foot, was less than 2%.

Typical sources of systematic errors in density measurements are: quality of the beam, thermal expansion of the gage assembly due to changing ambient temperature, variations of moisture content and resin content in measured boards, nonlinear effects of energy absorption, and accuracy of calibration samples.

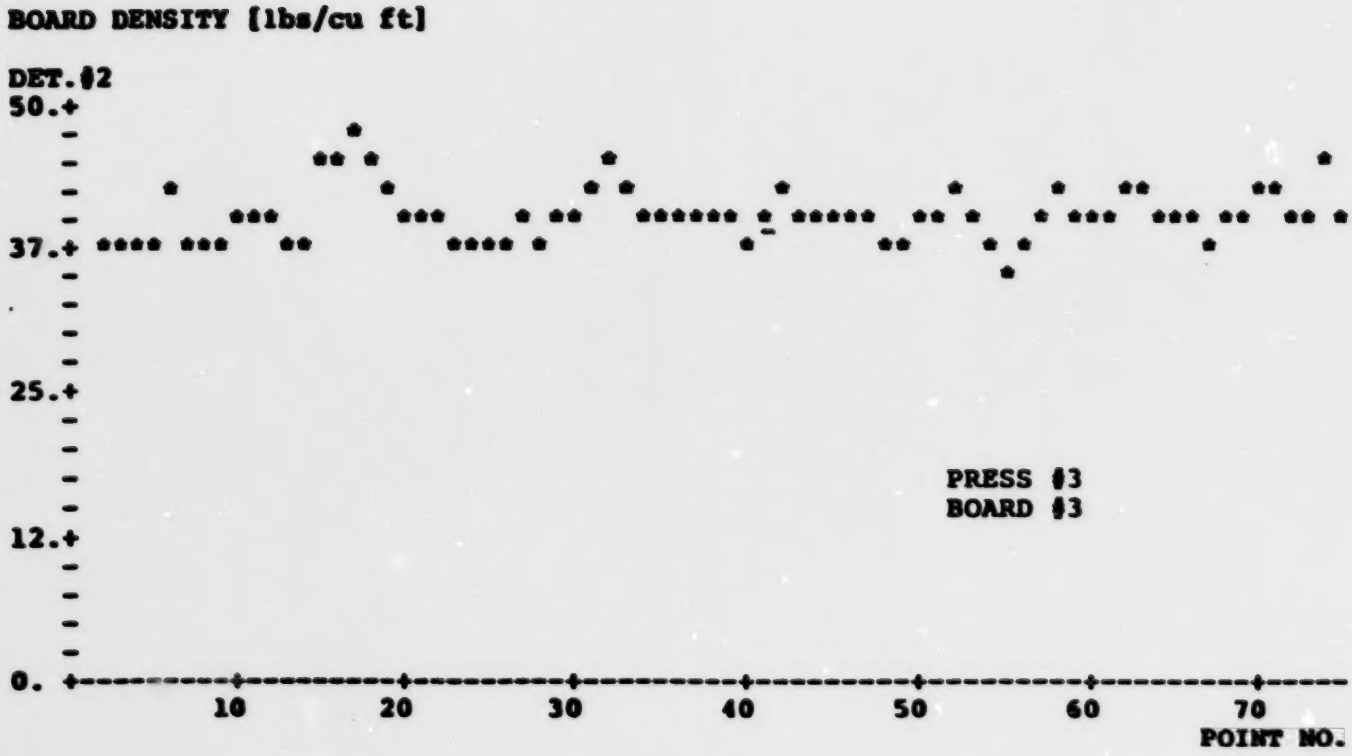


Figure 3. On-line measured (7.5 s) density profile, detector 2.

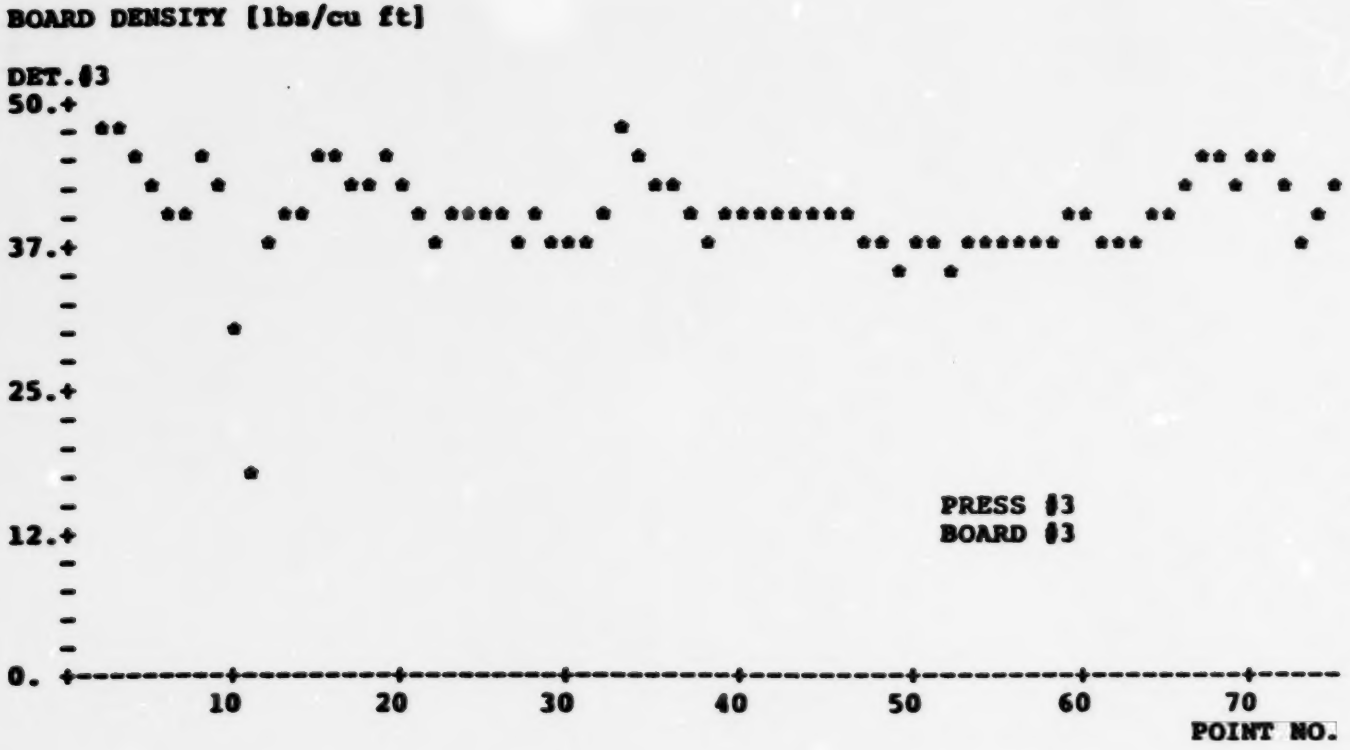


Figure 4. On-line measured (7.5 s) density profile, detector 3.

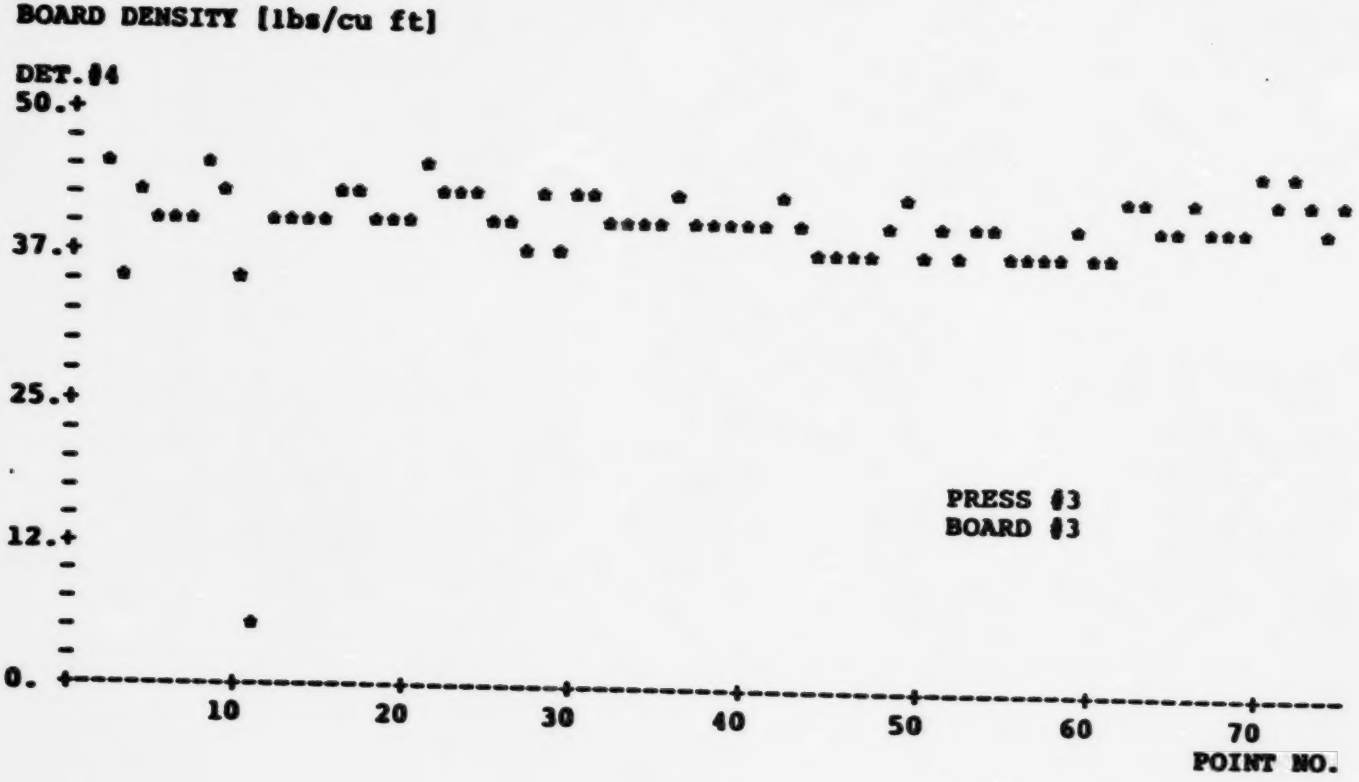


Figure 5. On-line measured (7.5 s) density profile, detector 4.

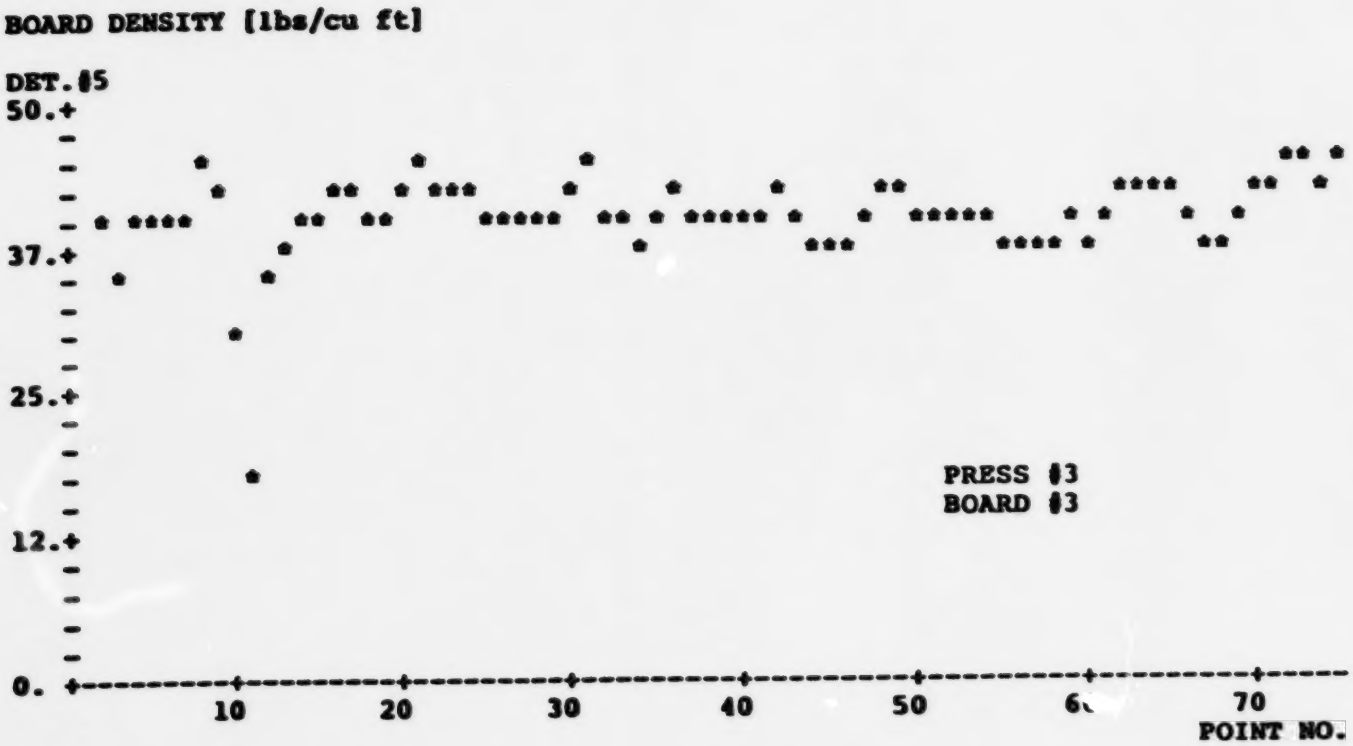


Figure 6. On-line measured (7.5 s) density profile, detector 5.

The quality of the Gamma radiation beam, its shape and diameter have been carefully engineered to meet the stringent demands of operating in an industrial environment. Each Gamma source assembly and detector assembly were precisely aligned so the beam scattering was eliminated. Dust and wood chips depositions that might deteriorate the beam were eliminated by pressurizing both compartments where sources and detectors were installed.

The effect of rapid ambient temperature changes due to the elevated temperature of boards leaving the press was compensated so each board was measured in practically steady conditions. Temperature gradients in the measurement area were neutralized by a constant air flow. Thermal expansion of the measuring assembly was slowed down by the massive construction of the metal housing frame. Its high heat capacity prevented rapid dimension changes due to ambient temperature variations and the distance between source and detector was kept constant during the time interval necessary for scanning of a single board. Reference level of the radiation exposure was regularly updated by the computer. The metal frame build of heavy gage steel resisted the impact of oncoming boards.

Variations in moisture content of measured boards influence their density. For proper density measurements using Gamma radiation technique the dependence of the effective mass

attenuation coefficient on moisture content should be analyzed. The effective mass attenuation coefficient Qe for wet wood depends on moisture content and on how much the two components, water and dry wood attenuate the Gamma radiation:

$$Qe = Fw\ Qw + Fa\ Qa \qquad (3.3)$$

where:

Qw - mass attenuation coefficient of dry wood in [sq cm/g],

Qa - mass attenuation coefficient of water in [sq cm/g],

Fw - weight fraction of dry wood in wet wood,

Fa - weight fraction of water in wet wood.

The effective weight of wet wood depends on dry wood weight Ww as follows:

$$We = Ww\ (1 + MC) \qquad (3.4)$$

where MC - is the moisture content, $0 < MC < 1$.

From (3.3) and (3.4) it can be found how the effective mass attenuation coefficient Qe changes with variations of the moisture content:

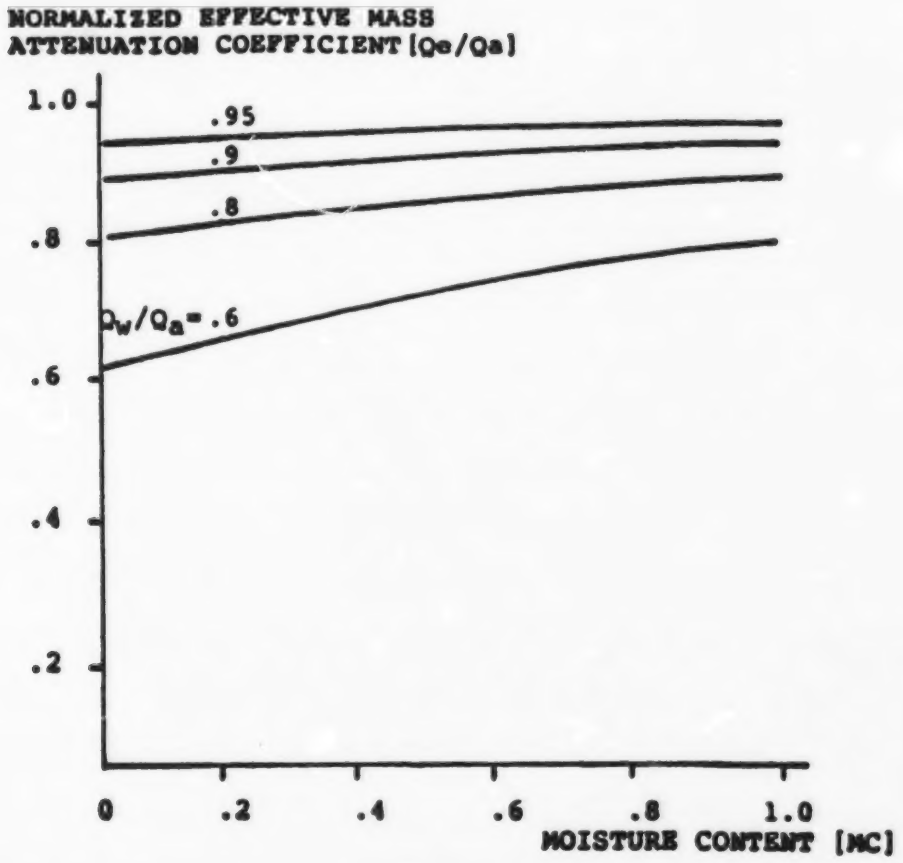
$$Qe/Qa = Qw/Qa \frac{1}{1 + MC} + \frac{MC}{1 + MC} . \qquad (3.5)$$

The normalized effective mass attenuation coefficient for wet wood Qe/Qa v.s. moisture content is shown in Figure 7.

For typical values of mass attenuation coefficients Qa = .196 [sq cm/g], Radiological Health Handbook (1970) and Laufenberg (1986), and Qw = .182 [sq cm/g], Laufenberg (1986), variations of moisture content between 5% and 10% will result in the effective attenuation coefficient change by less than .4%. Thus moisture content variations in board products leaving the press do not affect the validity of calibration constants used by the system for density measurements.

Similar analysis to the presented above can be used to determine the influence of resin content variations on board density measurements. Laufenberg (1986) gives mass attenuation coefficient values for typical resins used in composite wood products. Their values do not differ significantly from those for red oak, e.g. for Phenol-formaldehyde resin Q = .186 [sq cm/g], for Urea-formaldehyde resin Q = .189 [sq cm/g]. This means that resin content variations in the range +/- 1% will have negligible effect on the accuracy of density measurements.

Nonlinear effects of energy absorption, i.e. an effect of frequency dependent attenuation of radiation from a nonmonoenergetic source can cause errors in density measurements. This is the case when the actual thickness of the measured board



$$Qe/Qa = Qw/Qa \frac{1}{1 + MC} + \frac{MC}{1 + MC} \qquad (3.5)$$

Figure 7. Normalized effective mass attenuation coefficient Qe of wet wood v.s. moisture content MC.

differs from that of the calibration sample. An error depends on the bias between the two thicknesses and can be compensated for, Repsch et al. (1987). It has been experimentally verified, Repsch et al. (1987), that for thickness difference of 0.010" between measured board and a sample used for calibration an error in measured density is less then .2%. To avoid the necessity of compensation for nonlinear effects of energy absorption the calibration procedure in the described density measuring system is performed separately for each product according to its nominal thickness.

Density of the sample chosen as a calibration reference has to be determined with maximum precision that for conventional gravimetric methods can be maintained at a level of +/- 1%.

The worst case accuracy of density measurements presented in Figures 3 to 6 was estimated to be +/- 3% when all sources of errors are present at the same time, i.e.: moisture content, board composition and thickness differ significantly from values at calibration, which is normally not the case.

CONCLUSIONS

The purpose of this paper was to present the successful industrial application of on-line measurements of density of O.S.B. boards by Gamma-ray technique. The density data together with simultaneous measurements of board thickness provided for very effective quality control, immediate detection of inferior and defective boards, blow detection and optimization of the production cycle.

The computerized system for on-line density measurements was a fast, nondestructive and accurate measuring tool for monitoring entire board area. Each 24' by 8' board was uniformly covered with over 400 measuring points. This number could be increased by installing more Gamma-ray sources and detectors across the production line.

The system presented individual and average area densities of boards expressed in [kg/sq m] or [lbs/sq ft] (basic weight). It also provided volumetric density in [kg/cu m] or [lbs/cu ft], since measurements of boards thickness were simultaneously recorded. Accuracy of density measurements was +/- 3% at the line speed of 300 ft/min (90 m/min).

The system was safe, the sources of low energy radiation did not exceed 100 mCi and were contained in assemblies equipped with safety interlocks and electronically controlled shutters.

Variations in moisture content of measured boards did not significantly influence results obtained using Gamma radiation technique. Moisture content changes by 5% caused an error in density measurement less than .4%.

The system has been designed to operate in severe ambient conditions with temperature changes, dust and vibrations. Its reliability has been proven in existing installations.

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